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Study and development of diagnostic systems to characterise the extraction region in SPIDER

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SPIDER is a radio frequency (RF) driven negative ion source part of the Neutral Beam Test Facility (NBTF), prototype of the negative ion source of ITER's neutral beam injector. It is composed of 8 cylindrical drivers, capable of igniting the plasma through the inductive coupling with 4 radio frequency generators, each delivering up to 200kW. Its goal is to accelerate 50A of negative hydrogen ions up to 100keV, with beam uniformity within 10% over the entire beam cross section of approximately $2m^2$.

The experiment started its operations in 2018, and recently its capability of negative ion production in caesium operation has been tested. Results achieved until now are aligned with the ones obtained in similar test facilities, however, SPIDER presents some further challenges due to its dimensions, to the presence of more than one driver, and to the non-uniform plasma expansion. All these physical problems affect the uniformity of the extracted beam, hence, the machine has yet to reach the expected nominal performances and to improve it, at the end of 2021, SPIDER entered a major shutdown.

One the most important aspects studied during the first experimental campaign is uniformity, addressed both in terms of plasma and of caesium distribution. The latter is particularly relevant since its quality is directly related to the beam uniformity and divergence. To have more insight about these issues, monitoring the plasma properties in the extraction region is crucial, hence in the present contribution, the design and development of two new diagnostic systems is displayed: a movable Langmuir probe and a Retarding Field Energy Analyser (RFEA), both installed close to the plasma grid.

The first can provide a scan along the vertical direction of the main plasma parameters with better spatial resolution with respect to the existing set of fixed Langmuir probes embedded in the grid system, possibly interacting with other sensors to produce complementary measures.
The latter, instead, allows the monitoring of the positive ion energy distribution: positive ions, in fact, can be precursors of the negative ones produced at the caesiated surface, but also contributes the energy of negative ions and their extraction probability and thus collecting information about their energy distribution allows inferring details about the extracted negative ion beam.

The two diagnostics are designed focusing on the experimental constraint of integrating the diagnostics in a harsh and complex environment such as SPIDER plasma: a preliminary study of the placement inside the source is carried out, then the electrode of the movable probe and the RFEA sensor are dimensioned according to the spatial and energy resolution requested of the system.

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